TITLE OF THE INVENTION

ELECTRON MICROSCOPE

5   BACKGROUND OF THE INVENTION

[0001]

The present invention relates to an electron microscope for observing or detecting a surface or inside of a semiconductor wafer or a mask for exposing a

10   semiconductor pattern for faults and/or foreign objects, particularly to an electron microscope for observing or detecting a surface or inside using coordinates of faults and/or faults which were measured by another wafer/mask inspecting apparatus.

15   [0002]

Faults or objects on a semiconductor wafer or a mask for exposing a semiconductor pattern may give fatal problems to the semiconductor performances and reduce the efficiency of production of semiconductors.

20   [0003]

Therefore, to increase the production efficiency of semiconductors, it is required to remove unwanted objects from wafers and masks and faults from semiconductor patterns or mask patterns on the wafers as much as

25   possible. Therefore, it is thought to be very important to detect and observe wafers and masks for faults and/or objects (hereinafter generically described as faults) in the production of semiconductors and analyze the causes

of the faults.

[0004]

Recently, semiconductors have become smaller and smaller and their performance may be seriously damaged by even a fault of about 0.1 micron on a wafer. Conventionally an optical fault inspector or an optical object inspector (hereinafter generically described as an inspector) is used to locate faults on a wafer, move the field of view of the electron microscope to the location where the faults exist according to information on fault coordinates or the like obtained by said inspector, observe and identify the fault.

[0005]

However, a wafer/mask area to be observed at a time at a magnification is limited although it is dependent upon the size of a display screen of the electron microscope. Therefore, if fault coordinates measured by another inspector contain errors, the fault cannot be caught in the field of view of the electron microscope.

[0006]

Although various techniques have been supported to eliminate coordinate errors between the electron microscope and another inspector, such techniques cannot assure coordinate accuracies high enough to capture all faults in the field of view of the electron microscope.

[0007]

To search faults, the operator gradually moves the field of view of the electron microscope using a pointing

device (such as a mouse or a trackball) according to fault coordinates measured by another inspector and the location of the field of view of the electron microscope in reference to a wafer map, a die/chip diagram or an optical microscope image which is displayed separately. The conditions of observation of the electron microscope (such as a magnification) is calculated and set from data obtained by another inspector.

[0008]

However, at a high magnification, for example, x10,000 of the electron microscope, said conventional techniques do not have any means to show where the observation is made now and it is very difficult to move the field of view of the electron microscope to a position for observation.

[0009]

Further, to detect target faults in the field of view of the electron microscope or to set conditions of observation for the field, the conventional technique must calculate observation conditions such as a magnification for each fault from numeric data obtained by another inspector.

[0010]

Further, the conventional technique cannot use coordinate errors obtained in search of a fault easily for search of other faults, searching of the conventional technique is not efficient.

[0011]

Furthermore, in case both an area which was already observed by an electron microscope and an area which has not been observed are separately displayed on-screen, it sometimes happened that the conventional technique could

5 not change conditions of observation of the electron microscope or involuntarily initialized displays.

SUMMARY OF THE INVENTION

[0012]

10 An object of the present invention is to solve the aforesaid problems and to provide an electron microscope which enables the operator to move and set the field of view onto an area having a fault easily and accurately.

[0013]

15 To attain the aforesaid object, the present invention is characterized by the following.

[0014]

In accordance with the present invention, an electron microscope for observing a surface or inside of a

20 semiconductor wafer or a mask for exposing a semiconductor pattern for faults and/or foreign objects comprises

a function of loading measurement data of coordinates or sizes of faults or objects which were observed by

25 another wafer or mask inspecting apparatus, moving the field of view of the electron microscope to the area where said fault or object exists, and displaying the coordinates of faults or objects which were obtained by

another wafer or mask inspecting apparatus, the field of view of the electron microscope and its vicinity,

a function of a pointing device switch which moves the field of view of the electron microscope to a position which is pointed to by a pointer on said display, and

a function of changing the display as said field of view moves.

[0015]

The electron microscope in accordance with the present invention can display fault coordinates obtained by another inspectors, the field of view of the electron microscope and its vicinity, enlarge or shrink the views by operation of a pointing device or according to the movement of the field of view of the electron microscope or move the vicinity at a constant magnification.

[0016]

Further, the operator can move the field of view of the electron microscope by pointing to a desired position on the view with a pointing device.

[0017]

This enables the operator to know the position or area which is now observed and to move the field of view of the electron microscope easily to an area near the fault coordinates obtained by another inspector.

[0018]

Further, fault sizes are displayed on a screen showing the field of view and the display is changed

according to the condition of observation of the electron
microscope.

[0019]

Therefore, the operator can set conditions of fault
observation for the field of view of the electron
microscope and detect faults in the field of view
according to the fault shapes.

[0020]

Furthermore, the electron microscope in accordance
with the present invention has a function of displaying
fault coordinates and distances of the field of view
obtained by another inspector, storing the values, and
moving the field of view of the electron microscope
relatively by the stored distances.

[0021]

This function enables a coordinate error in a fault
searching to be used for search of another faults and
increase the efficiency of searching.

[0022]

Both an area which was already observed by an
electron microscope and an area which has not been
observed are separately displayed on-screen. These views
are changed when the conditions of observation of the
electron microscope are changed.

[0023]

This enables efficient observation of non-observed
areas only independently of condition of observation of
the electron microscope and prevents incomplete

observation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024]

5   One embodiment of the present invention will be explained below with reference to the accompanying drawings. This embodiment uses a three-button mouse as a pointing device. However, it is not intended as a definition of the limits of the present invention.

10   [0025]

FIG.1 is a schematic view of a system configuration of a scanning electron microscope which is an embodiment of the present invention. Electron beams 2 emitted from an electron gun 2 are condensed by an electron lens 3,

15   scanned and deflected 2-dimensionally by a defector 4, and applied to a specimen 5. When hit by the electron beams, the specimen generates secondary particles such as reflected electrons and secondary electrons according to the shape and material of the specimen. These secondary

20   electrons are detected by a detector 6 and amplified by an amplifier 7.

[0026]

A signal output from the amplifier 7 is A/D-converted into a digital image data by an image processor 8 and the

25   digital image data is realtime-displayed on the CRT of a workstation or a personal computer 9.

[0027]

The workstation or the personal computer 9 is

connected to a computer for controlling the electron
microscope by a transmission medium (not visible in
FIG.1). The operator can submit various commands from the
workstation or the personal computer 9 to the controlling
computer 10 to move the specimen stage 11 of the electron
microscope. As the specimen stage 11 moves, the field of
view of a specimen 5 also moves on the CRT of the
workstation or the personal computer 9.

[0028]

A semiconductor wafer or mask 12 is sent to an
optical inspecting apparatus 13 (another wafer/mask
inspector) and undergoes a fault inspection to detect
faults 14 on the wafer or mask 12. The optical inspecting
apparatus 13 collects information about coordinates and
sizes of faults 14 on the wafer or mask and outputs the
result.

[0029]

The wafer or mask 12 inspected by the optical
inspecting apparatus 13 is set on the specimen 11 of said
electron microscope. At the same time, the result of
inspection made by the optical inspecting apparatus 13 is
sent in an information medium (transmission, floppy disk,
MO, etc.) to the workstation or the personal computer 9
of the electron microscope.

[0030]

The workstation or the personal computer 9 corrects
the coordinates of the wafer or mask on the specimen
stage of the electron microscope according to the

coordinate information in said inspection result. Next, the specimen stage 11 of the electron microscope, that is the field of view is moved to the coordinates on which a fault 14 exists and the obtained microscope image is

5   displayed on the CRT of the workstation or the personal computer 9.

[0031]

FIG.2 shows a schematic screen layout of the CRT of the workstation or a personal computer 9. This screen

10   shows detailed information, the field of view, and its vicinity.

[0032]

The CRT screen 21 which is the display screen of the present invention shows an electron microscope image and

15   the graphical user interface (GUI) for the operator. The CRT screen comprises a field for an electron microscope image 22, a field for a pointer 23 as a pointing device, a field for a field-of-view 26 of the electron microscope, a field for a vicinity 24 of the field of view of the

20   electron microscope, a field for the center coordinates 25, and a field for a list 27 of inspection results of faults obtained by the optical inspecting apparatus 13. The field-of-view 26 of the electron microscope shows an observation area including the electron microscope image

25   22.

[0033]

Data obtained by the optical inspecting apparatus 13 contains the coordinates and size of each fault detected

by the optical inspecting apparatus. The field for a
vicinity 24 of the field of view of the electron
microscope shows fault positions and sizes according to
these kinds of information. These kinds of information
obtained by the optical inspecting apparatus 13 are
stored in the storage means of the workstation or the
personal computer 9.

[0034]

The pointing device to operate the GUI on the CRT
screen 21 is a three-button mouse 28 having a left button
29, a center button 30, and a right button 31.

[0035]

The operator takes a procedure explained below to
search a fault. The operator first selects a fault in the
fault list 27, clicks the left button 29 of the mouse on
it. The field of view of the electron microscope moves to
the coordinates of the selected fault.

[0036]

The view of the area in which the field of view
positions is displayed in the electron microscope image
field 22. At the same time, the coordinates of the fault
selected from the list is placed in the center 25 of the
vicinity field 24 and the field of view 26 is displayed
in the vicinity field to indicate the position of the
field of view relative to the center coordinates.

[0037]

In some cases, a selected fault is not found in the
new field of view at the coordinates of the fault

selected from the list which is obtained by the optical

inspecting apparatus. This is because of unreliable fault

coordinates obtained by the optical inspecting apparatus,

errors of the specimen stage of the electron microscope,

5   or a difference between the magnification of the optical

microscope and the magnification of the electron

microscope. In this case, the operator moves the field of

view 26 of the electron microscope to the vicinity of the

fault, that is, towards the center of coordinates 25

10   which indicate the coordinates of the fault obtained by

the optical inspecting apparatus.

[0038]

With this, the operator can recognize the position or

area of the current field of view of the electron

15   microscope relative to the fault coordinates obtained by

the optical inspecting apparatus at a glance and easily

move the field of view of the electron microscope at a

high magnification around the fault coordinates obtained

by the optical inspecting apparatus where a fault must

20   exist.

[0039]

[Embodiment 1]

Below will be explained an embodiment of the present

invention which enlarges or shrinks the field of view of

25   the electron microscope and its vicinity.

[0040]

FIG.3 is an illustration for explaining a procedure

of enlarging or shrinking the field of view of the

electron microscope and its vicinity and FIG.4 shows its flowchart.

[0041]

The operator moves the field of view of the electron microscope to the fault coordinates obtained by the optical inspecting apparatus. The field for the field-of-view 26 of the electron microscope, the vicinity field 24, the center of coordinates 25, and the actual size 41 of the vicinity field are displayed on-screen.

[0042]

By clicking the center button 30 or the right button 31 of the mouse anywhere in the vicinity field 24, the operator gets a step value 42 to change the actual size 41 of the vicinity field (S11). The operator can enter any step value.

[0043]

When the operator clicks the center button 30 (S12), the workstation or personal computer subtracts a step value from the current actual size 41 of the vicinity field and gets a new vicinity field size (S13).

[0044]

Next, the workstation or personal computer calculates the display size of the field of view 26 of the electron microscope relative to the new vicinity field (S16) and displays the enlarged field-of-view field and the enlarged vicinity field as shown in FIG.3 (b) (S17).

[0045]

When the operator clicks the right button 31 (S14),

the workstation or personal computer adds a step value to the current actual size 41 of the vicinity field and gets a new vicinity field size (S15).

Next, the workstation or personal computer calculates the display size of the field of view 26 of the electron microscope relative to the new vicinity field (S16) and displays the shrunk field-of-view field and the shrunk vicinity field as shown in FIG.3 (c) (S17).

[0046]

This function enables the operator to specify the rate of enlargement or shrinkage of the vicinity field of the fault coordinates obtained by another inspecting apparatus by numeric values. Accordingly, in case the deviation of fault coordinates can be estimated according to the types of optical inspecting apparatus or in case the deviation of fault coordinates can be estimated for each unit on a wafer, the operator can change sizes of the vicinity field and search a target fault efficiently.

[0047]

Further, the operator can recognize the size of the field-of-view field relative to the vicinity field at a glance and estimate the number of field-of-view fields required to observe before searching the result. This can easily tell the quantity of works required for searching.

[0048]

[Embodiment 2]

Below will be explained a second embodiment of the present invention which enlarges or shrinks the field of

view of the electron microscope and its vicinity. FIG.5
is an illustration for explaining a procedure of
enlarging or shrinking the field of view of the electron
microscope and its vicinity and FIG.6 shows its flowchart.

5 [0049]

The operator moves the field of view of the electron
microscope to the fault coordinates obtained by the
optical inspecting apparatus. Referring to FIG.5 (a), the
field for the field-of-view 26 of the electron microscope,
10 the vicinity field 24, the center of coordinates 25, and
the actual size 41 of the vicinity field are displayed
on-screen.

[0050]

In some cases, a selected fault is not found in the
15 new field of view at the coordinates of the fault
selected from the list which is obtained by the optical
inspecting apparatus 13. This is because of unreliable
fault coordinates obtained by the optical inspecting
apparatus, errors of the specimen stage of the electron
20 microscope, or a difference between the magnification of
the optical microscope and the magnification of the
electron microscope.

[0051]

In such a case, to observe a target fault as an
25 electron microscope image, the electron microscope of
this embodiment enlarges or shrinks the vicinity field 24
as the field-of-view field 26 moves without changing the
field-of-view field 26 in the vicinity field 24.

[0052]

The operator moves the field of view by operating the pointing device and gets a step value to enlarge or shrink the vicinity field (S21). The operator can enter any step value.

[0053]

Next, the workstation or personal computer checks whether the new field of view (after movement) is in the vicinity field. As shown in FIG.5 (b), if the field of view 26 is not in the vicinity field, the entered step value 42 is added to the actual size of the current vicinity field size (S23). As shown in FIG.5 (c), the result is used as the actual size 42 of a new vicinity field (S24). With this, the new shrunk field-of-view field and the new shrunk vicinity field are displayed (S25).

[0054]

When the field of view is in the vicinity field, the entered step value 42 is subtracted from the actual size 41 of the current vicinity field (S26).

[0055]

Next, the workstation or personal computer checks whether the new field of view (after movement) is in the vicinity field (S27). If the field of view 26 is in the vicinity field as shown in FIG.5 (d), the new enlarged field-of-view field and the new enlarged vicinity field are displayed (S25) with the result of calculation as the actual size 41 of a new vicinity field (S24) as shown in

FIG.5 (e).

[0056]

In the other cases, the actual size 41 of the vicinity field is not changed and the field-of-view field and the vicinity field will be neither enlarged nor shrunk.

[0057]

Each time the operator moves the field of view to detect a fault in the field of view, the above steps are repeated.

[0058]

With this, the field around the fault coordinates is enlarged or shrunk with the field-of-view field displayed on-screen even when the field of view of the electron microscope is moved to anywhere. Therefore, even when a deviation from the fault coordinate cannot be estimated in advance, the operator can recognize the positional relationship between the field of view of the electron microscope and the fault coordinates obtained by another inspecting apparatus just by moving the field of view and can search faults easily.

[0059]

[Embodiment 3]

Below will be explained a third embodiment of the present invention which moves the vicinity field without changing the magnitude of the field of view of the electron microscope and the magnitude of the vicinity field. FIG.7 is an illustration for explaining a

procedure of moving the vicinity field according to the movement of the field of view and FIG.8 shows its flowchart.

[0060]

5   The operator moves the field of view of the electron microscope to the fault coordinates obtained by the optical inspecting apparatus. Referring to FIG.7 (a), the field for the field-of-view 26 of the electron microscope, the vicinity field 24, the center of coordinates 25, and

10   the actual size 41 of the vicinity field are displayed on-screen.

[0061]

Similarly in the above embodiments, a selected fault is not found in the new field of view at the coordinates

15   of the fault obtained by the optical inspecting apparatus and the deviation cannot be estimated.

[0062]

To get an electron microscope image of a target fault in such a case, this embodiment moves the center

20   coordinates 25 in the vicinity field 24 as the field of view 26 of the electron microscope moves while keeping the field of view displayed in the vicinity field 24.

[0063]

After the operator moves the field of view by

25   operating the pointing device, the workstation or personal computer checks whether the new field of view (after the movement) is in the vicinity field (S31). If the field of view 26 is not in the vicinity field as

shown in FIG.7 (b), the current center coordinates is moved by the actual size 41 of the vicinity field along the movement of the field of view as shown in FIG.7 (c) (S32).

5   [0064]

Next, the workstation or personal computer calculates the position of the field of view relative to the center coordinates 25 (S33) and checks whether the center coordinates 25 are equal to the fault coordinates

10   obtained by another inspecting apparatus (S34). If the center coordinates are not equal to the fault coordinates, the workstation or personal computer deletes the center coordinates 25 as shown in FIG.7 (d) (S36), displays an arrow 45 oriented to the fault coordinates obtained by

15   the optical inspecting apparatus (S36), and updates the display of the field of view 26 (S37).

[0065]

If the field of view moves out of the vicinity field as shown in FIG.7 (e), the center coordinates 25 is moved

20   by the actual size 41 of the vicinity field as shown in FIG.7 (f) (S32).

[0066]

When the new center coordinates 25 (after this movement) match with the fault coordinates obtained by

25   another optical inspecting apparatus, the workstation or personal computer displays the center coordinates 25 as shown in FIG.7 (g) (S38), deletes the arrow 45 which is oriented to the fault coordinates obtained by the optical

inspecting apparatus (S39), and updates the display of
the field of view 26 (S37).

[0067]

Each time the operator moves the field of view to

5   detect a fault in the field of view, the above steps are
repeated.

[0068]

With this, the center coordinates are moved by the
actual size of the vicinity field without changing the

10   display size of the field of view of the electron
microscope while the field of view is moved anywhere.
Further this embodiment indicates a direction in which
the fault coordinates obtained by the optical microscope
exist. This enables the operator to search faults in each

15   field of an accessible size without a fail.

[0069]

[Embodiment 4]

FIG.9 shows an example of displaying a fault in the
field-of-view field in accordance with the present

20   invention.

[0070]

The workstation or the personal computer calculates
the size of a fault in the field-of-view field 26 within
the vicinity field 24 from X and Y coordinates of a fault

25   obtained by an optical inspecting apparatus and displays
the shape 51 (e.g. an ellipse) of the fault in the field-
of-view field 26. The fault can have any shape (e.g. a
rectangle).

[0071]

If information about fault shapes and compositions are available from the optical inspecting apparatus 13, it is also possible to simulate so that the composition information can be recognized.

[0072]

When the magnification of the electron microscope image is reduced, the actual size 41 of the vicinity field is increased in inverse proportion to the magnification and the shape 51 of the fault is reduced with the display ratio of the field-of-view field 26 to the vicinity field 24 unchanged.

[0073]

When the magnification of the electron microscope image is increased, the actual size 41 of the vicinity field is decreased in inverse proportion to the magnification and the shape 51 of the fault is increased with the display ratio of the field-of-view field 26 to the vicinity field 24 unchanged.

[0074]

With this, the operator can get the relative size of a fault in the field-of-view field at a selected magnification of the electron microscope. Therefore, even when a fault is not actually in the field of view, the operator can set a magnification of the electron microscope fit for searching or observation.

[0075]

As the shape of a fault is displayed in the field-of-

view field of the electron microscope, the operator can easily recognize a target fault when the fault is hard to be distinguished from a pattern or a plurality of faults exist in the field-of-view field.

5   [0076]

[Embodiment 5]

FIG.10 shows an example of moving the field of view of the electron microscope and displaying a distance between the center of the field of view and the fault

10   coordinates.

[0077]

The operator moves the field-of-view field of the electron microscope toward the fault coordinates obtained by the optical inspecting apparatus 13.

15   The field for the field-of-view 26 of the electron microscope, the vicinity field 24, the center of coordinates 25, and the distance 61 between the center of the field of view and the fault coordinates are displayed on-screen.

20   [0078]

In this status, the center coordinates 25 of the field-of-view field matches with the center coordinates 25 of the vicinity field 24. Therefore, the distance between the center of the field of view and the fault

25   coordinates is X=0 and Y=0.

[0079]

When the operator moves the pointer 23 (of the pointing device) to a position in the vicinity field 24

to which the operator wants to move the field of view of
the electron microscope and click the left button 29 of
the mouse, the field of view of the electron microscope
moves to the selected position. The workstation or the
5   personal computer calculates the distance between the
center coordinates 25 of the vicinity field 24 and the
center coordinates 62 of the field-of-view field and
displays the result in the "Distance between the region
of interest and the coordinates of the fault" field 61.

10   [0080]

When the operator clicks the SAVE button 63, the
values set in the "Distance between the region of
interest and the coordinates of the fault" field 61 are
saved. Next, the operator moves the field of view to
15   another fault coordinates and click the MOVE button 64.
The field of view of the electron microscope is
relatively moved by a distance which was saved latest.

[0081]

As explained above, the operator can easily move the
20   field of view of the electron microscope to any place
near the fault coordinates. Therefore, this embodiment is
very effective to move the field of view of the electron
microscope directly and easily to any place near the
fault coordinates in case a deviation of a fault is
25   estimated.

[0082]

With this, when a fault is detected in the field of
view, the operator can get the distance between the fault

coordinates obtained by the optical inspecting apparatus 13 and the actually-observed fault coordinates easily from the content in the "Distance between the region of interest and the coordinates of the fault" field 61. This is very effective when the fault coordinates obtained by the optical inspecting apparatus 13 are not reliable or affected by a stage error. This embodiment can correct such overall coordinate errors between the optical inspecting apparatus 13 and the electron microscope in accordance with the present invention.

[0083]

Further, if it is assumed that the other fault has almost the same error, the operator can search the fault efficiently by moving the field of view of the electron microscope to the same deviated position by simple button operations.

[0084]

[Embodiment 6]

FIG.11 shows an example of separately displaying areas which are already observed and areas which have not been observed yet in accordance with the present invention.

[0085]

The field-of-view field 26 moves in the vicinity field 24 as the field of view of the electron microscope moves. In this case, the areas 71 which were already observed are displayed in different colors. This is also true when the field of view of the electron microscope is

rotated.

[0086]

Further, when the vicinity field including the field of view of the electron microscope is enlarged or shrunk, the areas 71 which were already observed are enlarged or shrunk according to the size of the vicinity field.

[0087]

This prevents re-observation of the already-observed areas or skipping of observation of areas which have not been observed as the areas which were already observed are clearly distinguished from areas which have not been observed even when the field of view of the electron microscope is moved or rotated or the vicinity field including the field-of-view field is enlarged or shrunk.

[0088]

The present invention can provide an electron microscope for reviewing faults which are detected by an optical inspecting apparatus, wherein said electron microscope can position its field of view easily and accurately on a target fault regardless of positional errors between different kinds of microscopes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a schematic view of a system configuration of a scanning electron microscope which is an embodiment of the present invention.

FIG.2 shows a schematic screen layout of the CRT of the workstation or a personal computer to operate the

electron microscope of the present invention, including a field-of-view field and a vicinity field.

FIG.3 is an illustration explaining a procedure of enlarging or shrinking the field of view and its vicinity

5   of the electron microscope of Embodiment 1.

FIG.4 is a flowchart explaining a procedure of enlarging or shrinking the field of view and its vicinity of the electron microscope of Embodiment 1.

FIG.5 is an illustration explaining a procedure of

10   enlarging or shrinking the field of view and its vicinity of the electron microscope of Embodiment 2.

FIG.6 is a flowchart explaining a procedure of enlarging or shrinking the field of view and its vicinity of the electron microscope of Embodiment 2.

15   FIG.7 is an illustration explaining a procedure of moving the vicinity field according to the movement of the field-of-view field in Embodiment 3.

FIG.8 is a flowchart explaining a procedure of moving the vicinity field according to the movement of the

20   field-of-view field in Embodiment 3.

FIG.9 is a schematic diagram explaining a procedure of displaying a fault in the field-of-view field of Embodiment 4.

FIG.10 is a schematic diagram explaining a movement

25   of the field-of-view field of the electron microscope of Embodiment 5 and a procedure of displaying a distance between the fault coordinates and the center of the field-of-view field.

FIG.11 shows an example of separately displaying areas which are already observed and areas which have not been observed in Embodiment 6.